Instruments for in-situ measurements of the gas giants and their satellites

Instruments for *in-situ* measurements of the gas giants and their satellites

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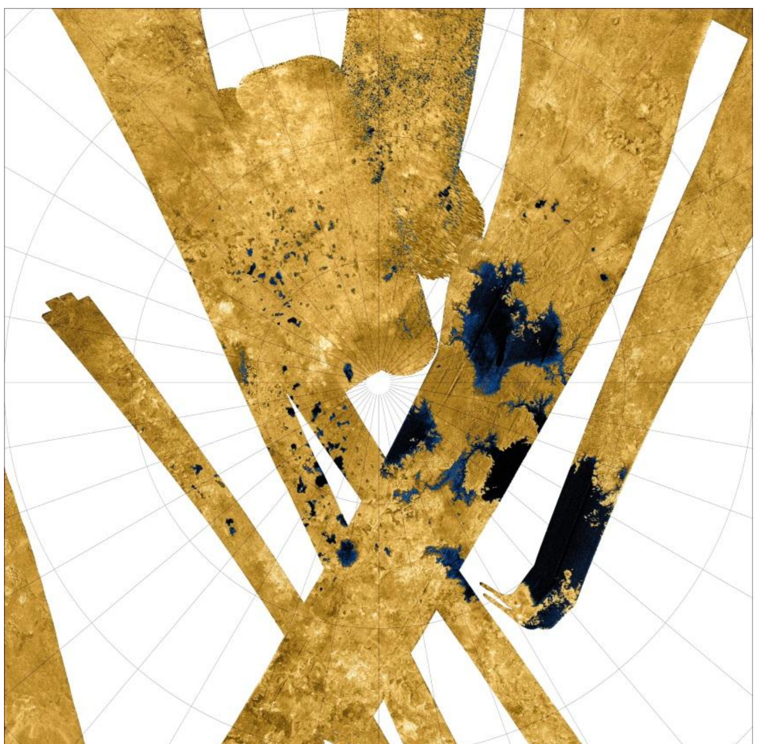
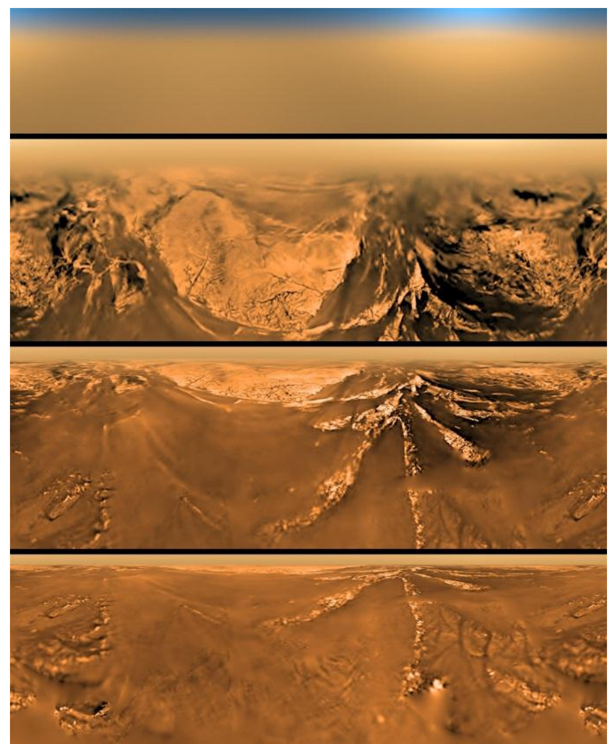
The Open University

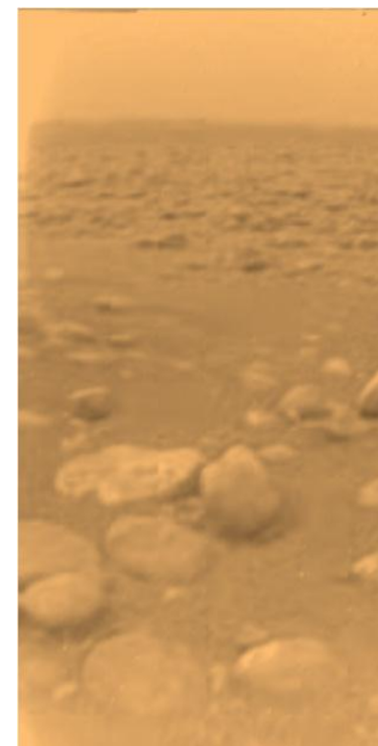
In-situ measurements

Advantages:

- Scale from km to m, mm and μm
- Ground truth, physical properties
- Direct analysis of chemical composition





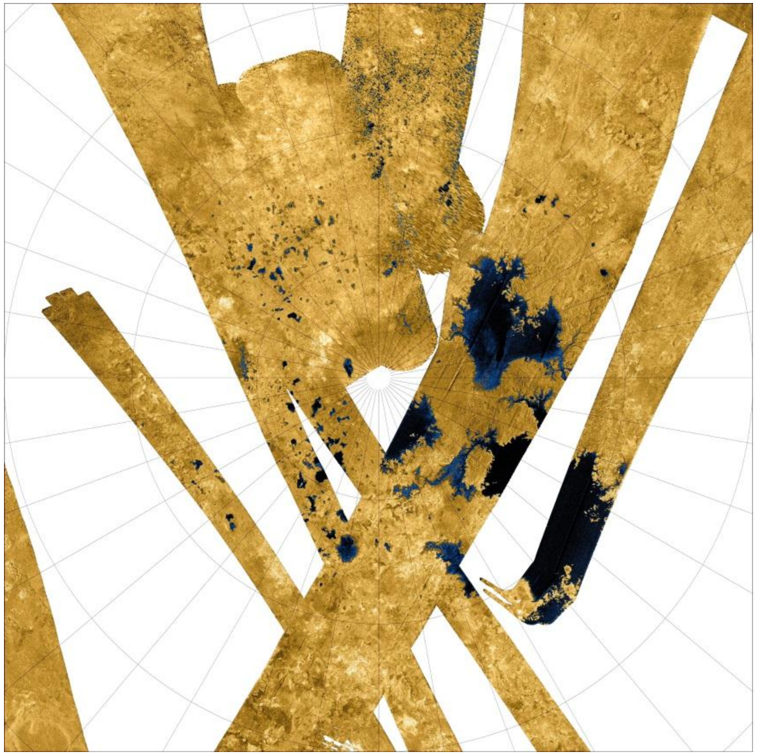


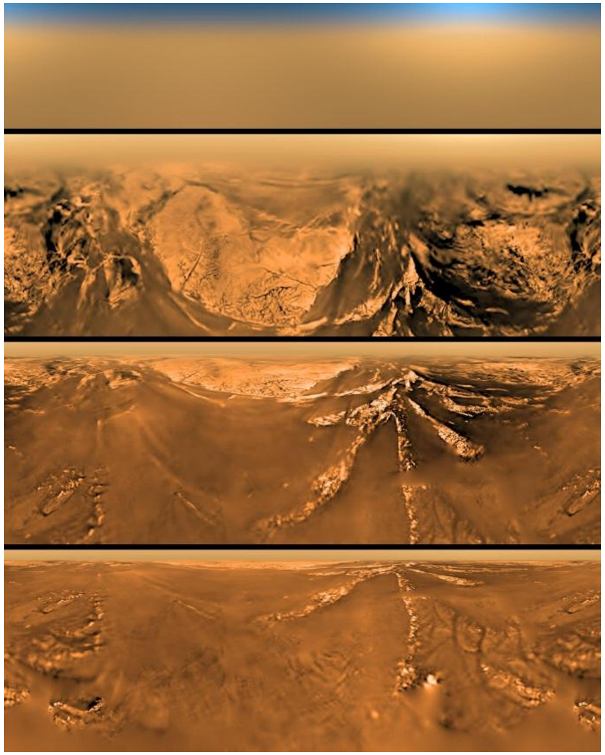
In-situ measurements

Disadvantages:

- Short time scale
- One location
- Landing – high risk
- Limited payload mass/power

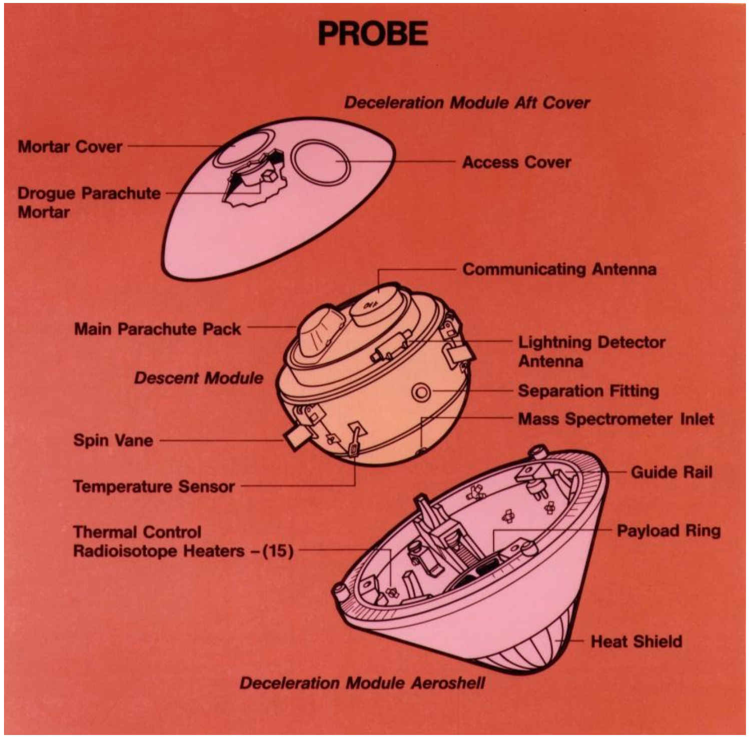
Genesis landing





Planetary probes

Galileo at Jupiter



Kronos (cosmic vision 2007)

Atmospheric Structure Instrument

- Density, pressure temperature

Doppler Wind Experiment

Nephelometer

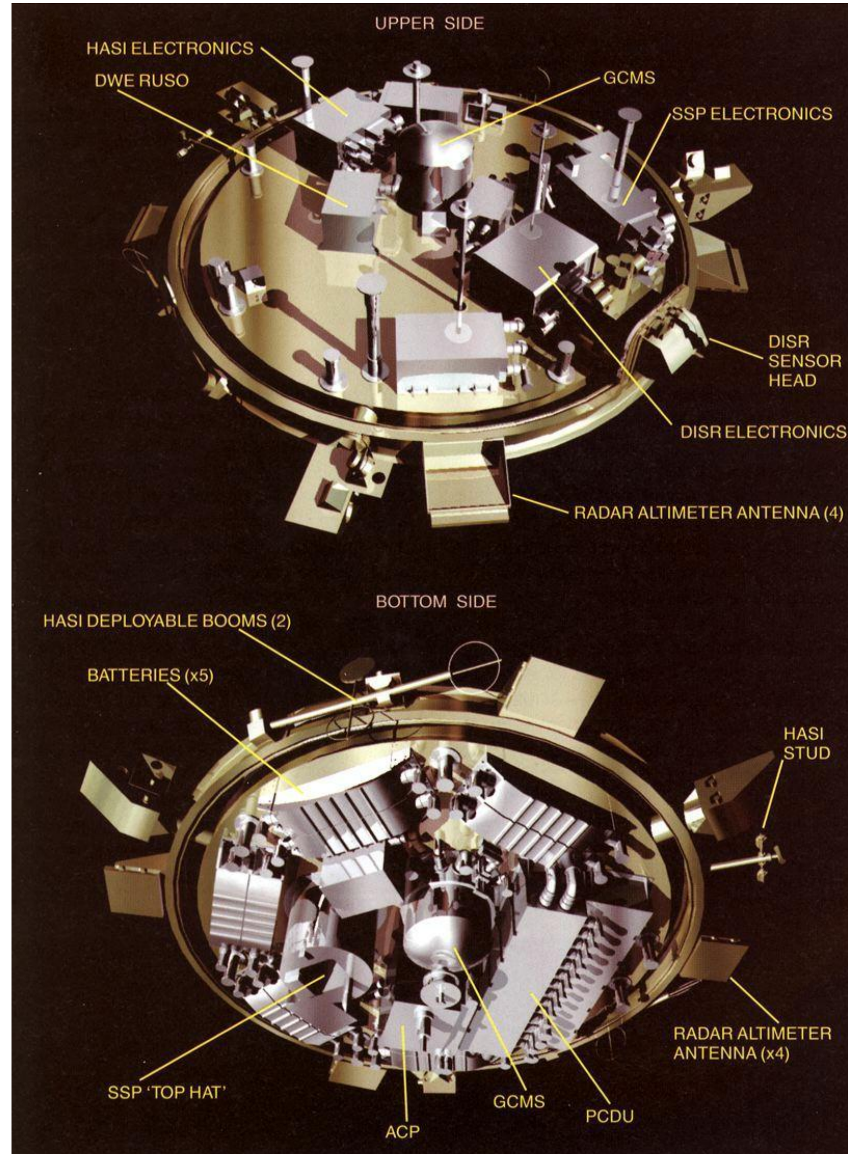
- aerosol size, shape composition

Elemental Composition and isotopes

- D/H $^{13}C/^{12}C$ $^{15}N/^{14}N$ He, Ne, Ar Kr, Xe

Heritage Galileo + Rosetta Ptolemy

Titan - Huygens



Descent Imager and Spectral Radiometer

Doppler Wind Experiment

Huygens Atmospheric Structure Instrument

Surface Science Package

Gas Chromatograph and Mass Spectrometer

Aerosol Collector and Pyrolyser

Titan Atmospheric Chemistry

Cassini INMS and CAPS detected organics >10000 amu at 950km

Formation pathways?
Types of organics?
How complex are organics?
Are O containing organics formed?
Chirality?

Energetic particles

Sunlight

Molecular CH_4 and N_2

Ionisation
$C_2H_5^+$, $HCNH^+$
CH_5^+, $C_4H_5^+$

Dissociation
C_2H_2, C_2H_4
C_2H_6, HCN

Benzene (C_6H_6) and other organics(100 – 350 amu)

↓

High mass organics >10000 amu

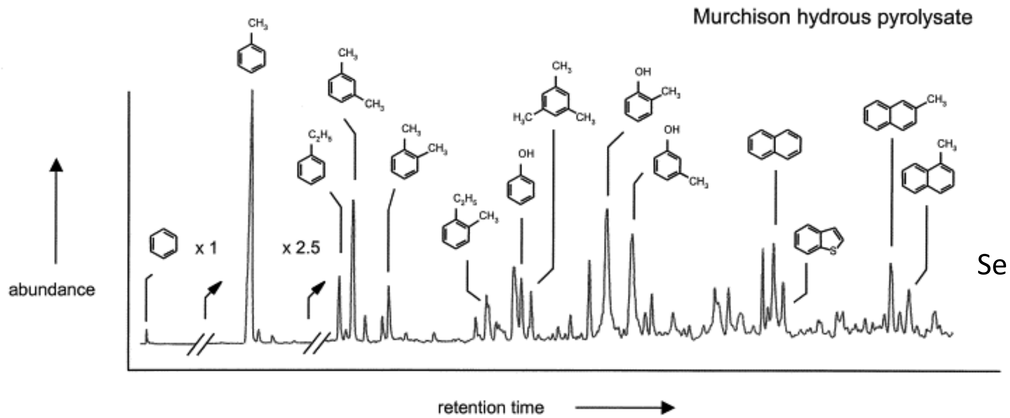
↓

Tholins

Analysis Organics

GC - MS

GC – separates compounds, identification by MS



Sephton et al 1998

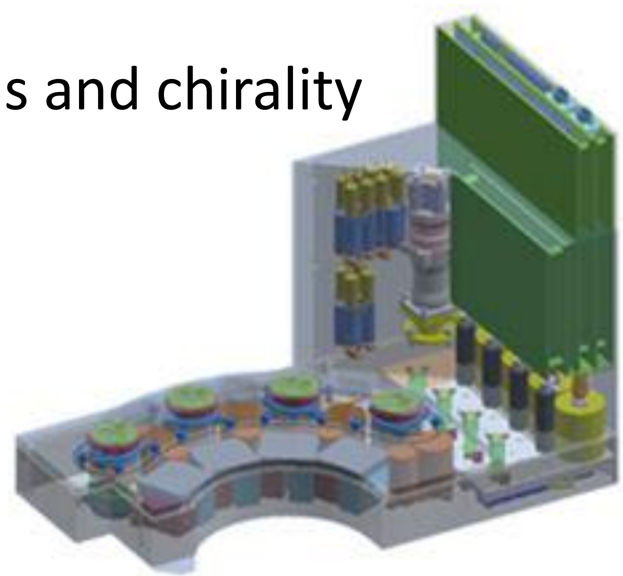
Derivatisation required for amino acids and chirality

Life Marker chip - ExoMars

Target specific molecules

High sensitivity

~1.5 kg

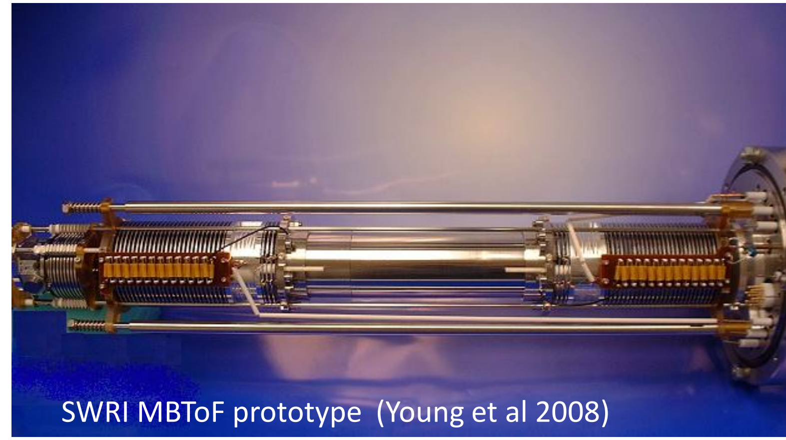


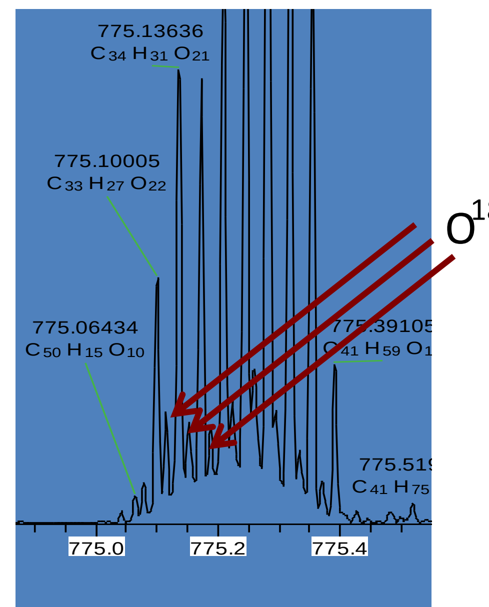
High Resolution Mass Spectrometry

Time of Flight
Rosetta, ROSINA and COSAC
Mass range 2-500 M/ΔM 500

MBToF
Mass range 2-10 000 M/ΔM 10 000

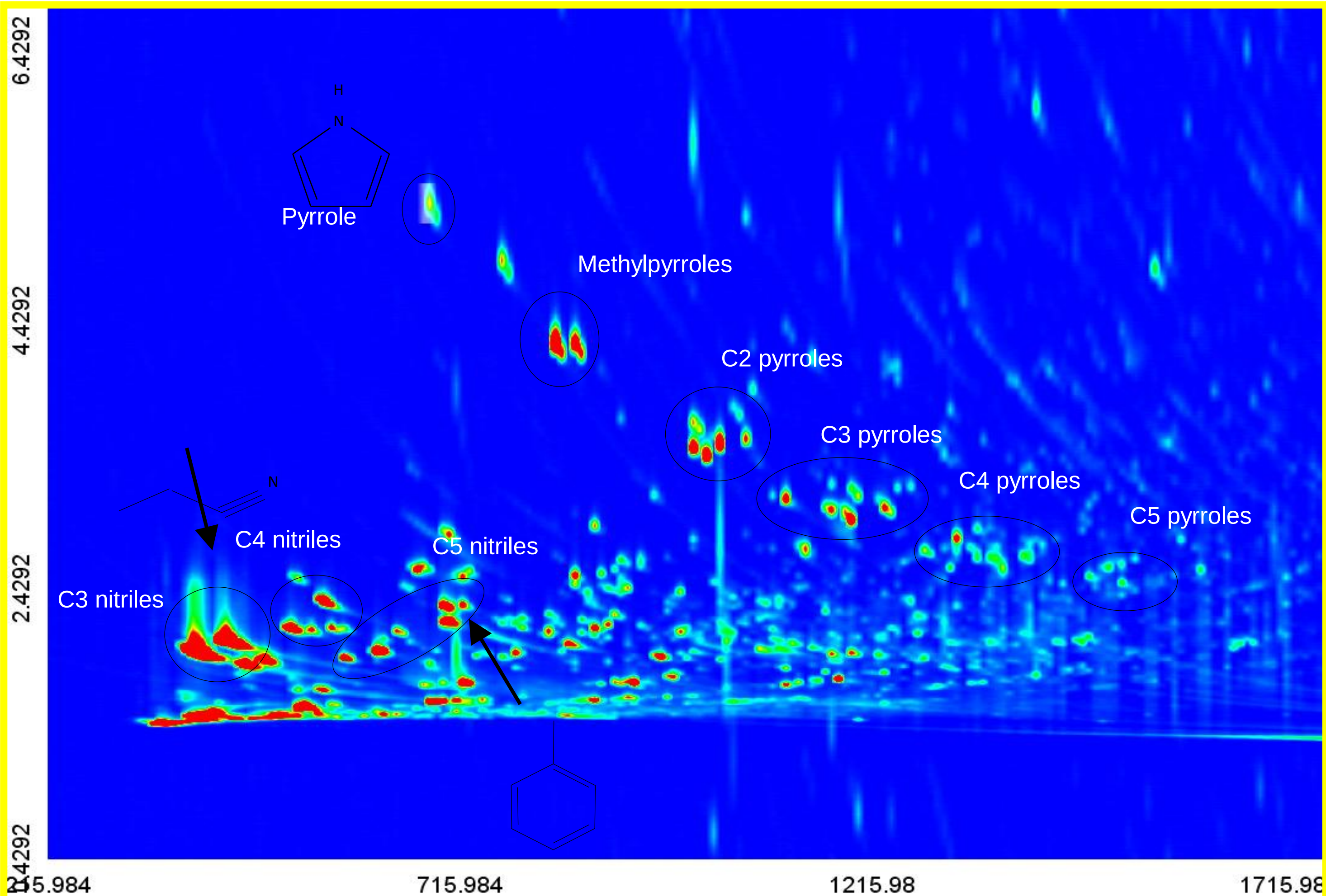
Orbitrap
M/ΔM 100 000


SWRI MBToF prototype (Young et al 2008)



GC x GC MS

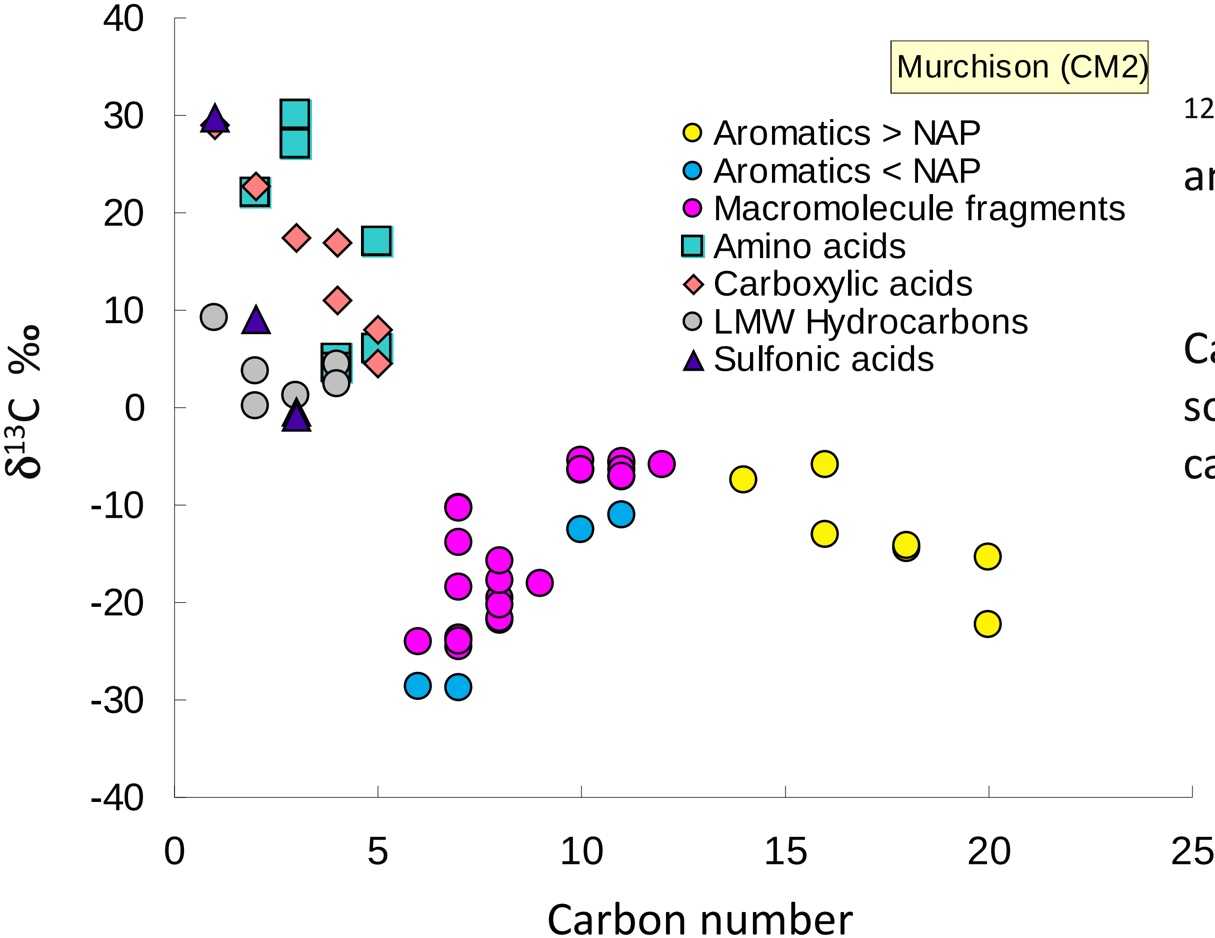
Combination of non-polar column followed by polar column



GCxGC analysis of tholin sample

MS requirements
M >600 amu,
F >10Hz
M/ΔM >600

Stable Isotopes (1‰)



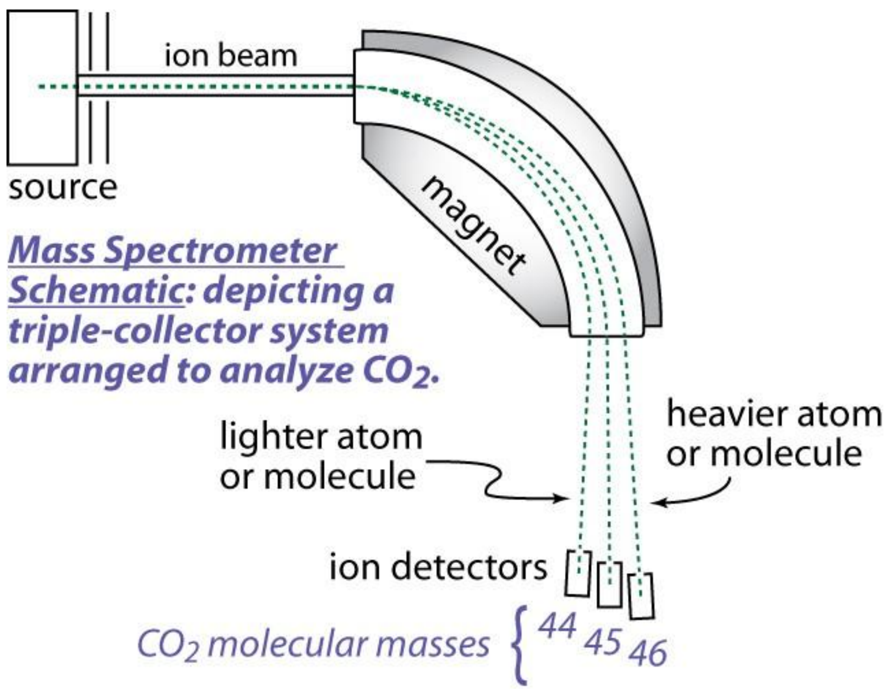
^{12}C bonds preferably made and broken

Carboxylic acids formed by solid phase reactions with carbonates

$$\delta^{13}C = \left\{ \frac{(^{13}C/^{12}C)_{sample}}{(^{13}C/^{12}C)_{reference}} - 1 \right\} \times 1000\ ‰$$

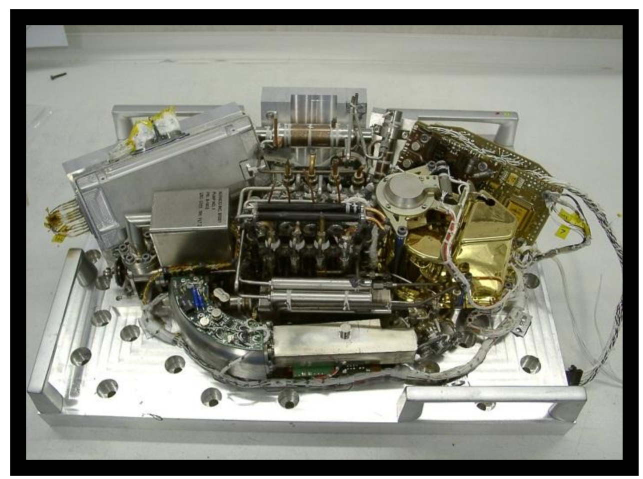
Isotopic Analysis

Isotope MS



Stable magnetic field
Simultaneous collection
– separate ions in space
Faraday cup collectors
Flat topped peaks

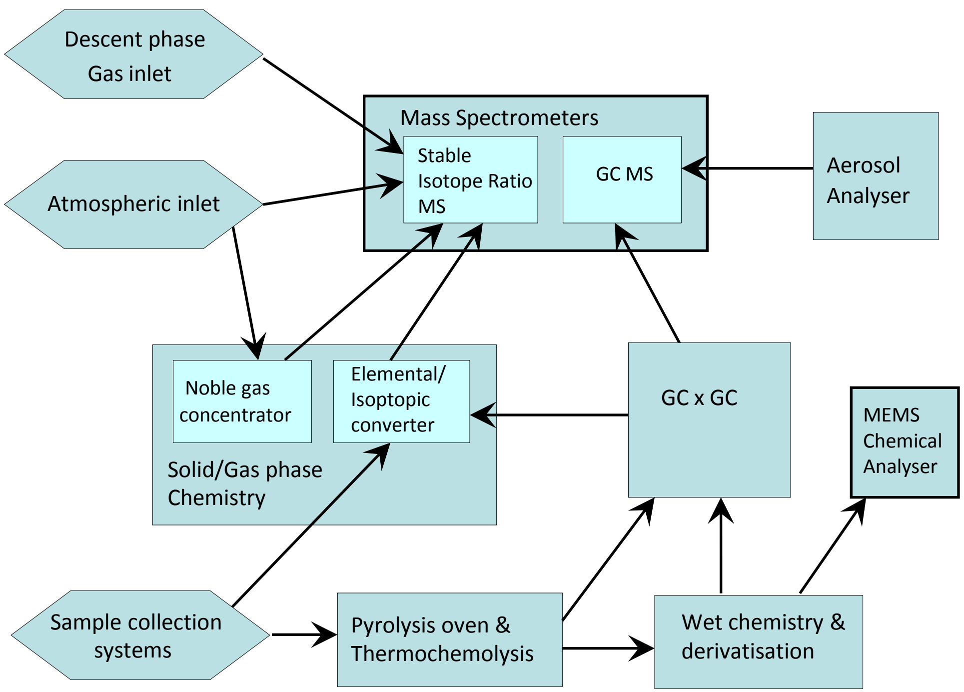
Chemical processing
Reference material



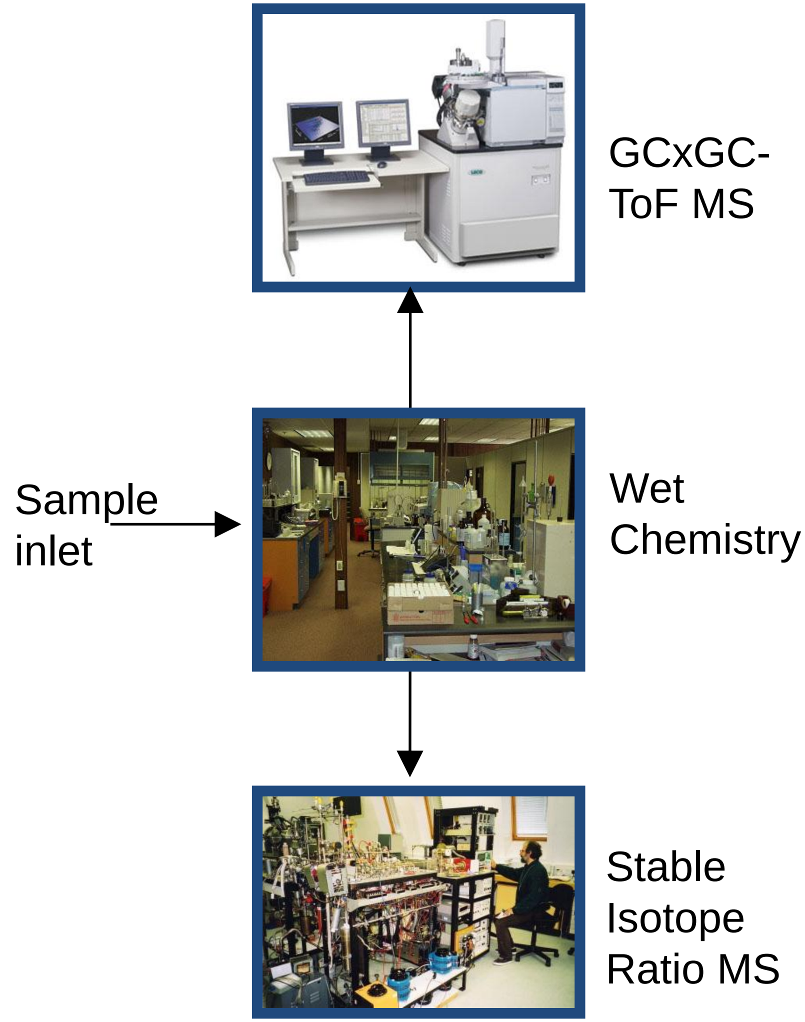
Heritage Pheonix, TEGA
Beagle2, GAP (6kg)

Curiosity, SAM TLS
$^{18}O/^{16}O$, $^{13}C/^{12}C$ precision ~1‰

System diagram

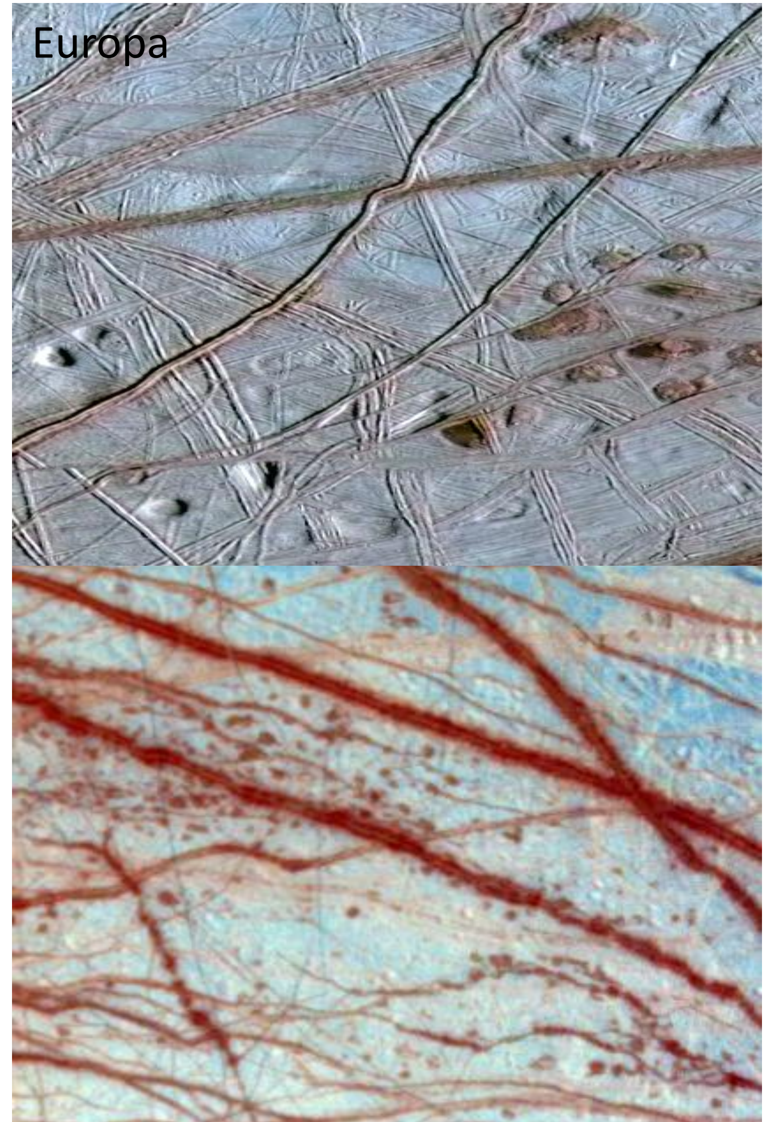


GCxGC, High resolution MS, targeted detection, astrobiology
High precision Isotope MS

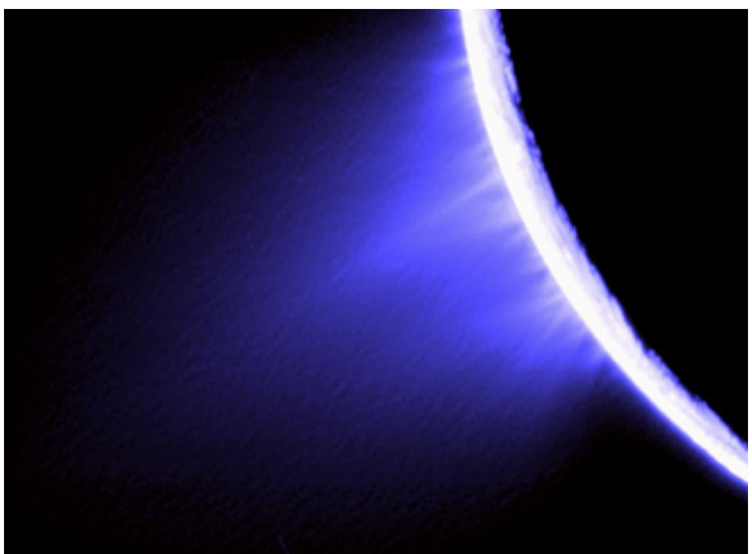


In-situ measurements at Europa / Enceladus

In-situ by orbiter
Subterranean ocean
No atmosphere
Hard surface

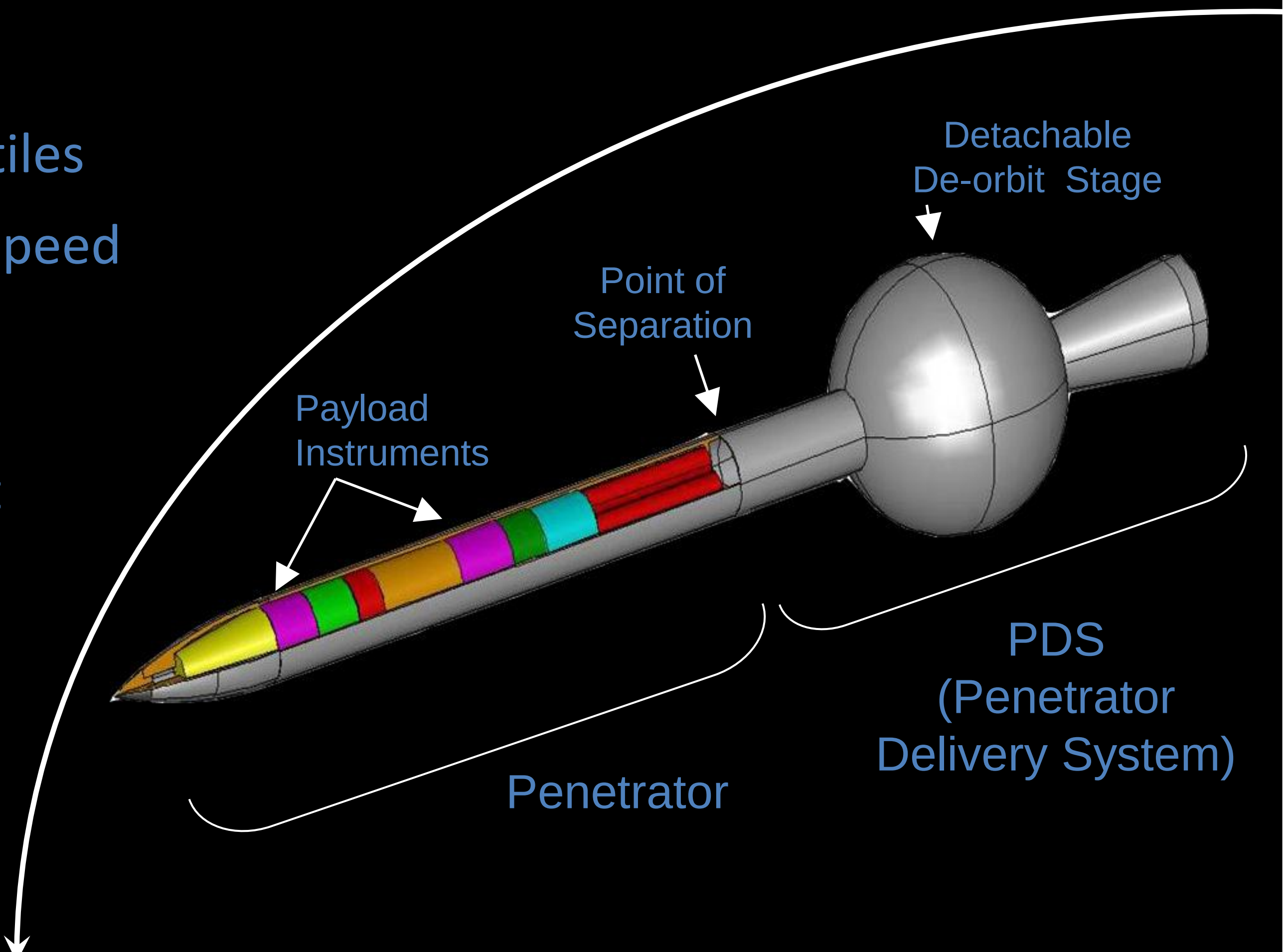


Enceladus



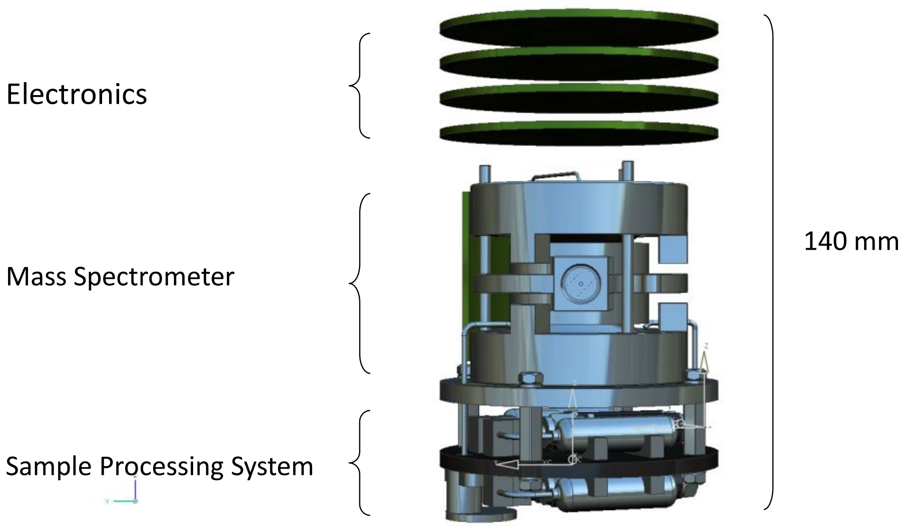
Penetrators

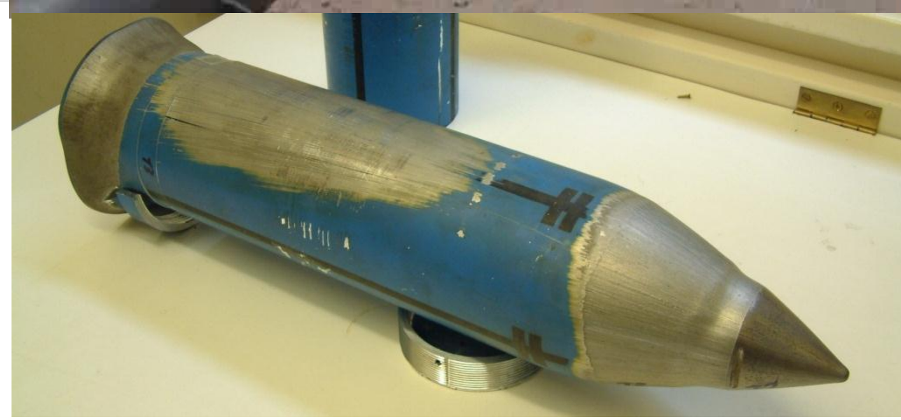
- Instrumented projectiles
- Survive high impact speed
- Penetrate surface
  ~ few metres
- An alternative to soft landers
- Low mass/lower cost
  => multi-site deployment



Penetrator trials Pendine

MS Overview





Heritage Rosetta, Ptolemy
Mass range 10 – 150 amu
Unit mass resolution
Mass ~ 0.5kg
Power 2W

Summary

- Determination of noble gas concentration
- Measurement of noble gas isotopes
- Measurement of D/H $^{13}C/^{12}C$, $^{15}N/^{14}N$, $^{18}O/^{16}O$ and $^{17}O/^{16}O$ isotopes
- Detailed organic chemical analysis M/DM > 10 000 and mass range >. 10000
- Possibility of measurements on surface of Europa and Enceladus